Volume 40 December, 1954 *Number 12*

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Progress in Railroad Bearing Lubrication

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

This 7-ton test machine at Texaco's Beacon Research Laboratories puts railroad journal bearing lubricants through their paces. It simulates speeds up to 100 m.p.h., applies 50,000-lb. vertical loads and 15,000-lb. horizontal loads, duplicates the jolts caused by track joints, flat wheels, side sway and other irregular loadings.

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THE TEXAS COMPANY

LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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PROGRESS IN RAILROAD BEARING LUBRICATION

THE Encyclopaedia Brittanica defines a bearing as "the stationary support which carries a moving element of a machine and maintains the proper relationship of the moving element to the stationary element. A bearing usually allows the moving element perfect freedom for one form of motion, such as a rotation, and at the same time prevents any other form of motion". In most bearings, the moving surfaces are separated by rollers, balls, or a lubricant film and, in general, are classified either as rolling friction or sliding friction bearings.

Since bearings are an integral part of almost every machine, proper functioning of the machine depends very materially upon the proper functioning of the bearings. In addition to the bearing design and construction, the lubricant used in the bearing plays a most significant role in the performance of the bearing and, in turn, of the machine itself.

Without a doubt, most bearings are used for support of rotating shafts or journals. On American railroads alone, there are actually millions of such bearings employed as locomotive and car journal bearings. As in other machinery, the proper functioning of this rolling stock is dependent upon bearing performance.

Railroad Bearing Research Father of Lubrication Theory

It is particularly interesting to note that the study of railroad bearing lubrication provided the stimulus for the development of the theoretical basis of hydrodynamic lubrication fundamentals. It was in 1885 that Beauchamp Tower conducted a series of experiments in England on railway bearings in which he measured the relationships between friction, loads, and lubricant type. In his test work in which he used lard, rapeseed, sperm and mineral oils, he found, quite by chance, that there was an actual fluid pressure developed within the oil film. He proceeded to find this pressure distribution experimentally.

In 1886, Professor Osborne Reynolds, at the University of Manchester, clarified Tower's work in a publication of a mathematical analysis in which he laid down the principles of the basic theory of hydrodynamic lubrication as it is known today. The most significant result of Reynolds theory is the principle of the wedge-shaped or converging lubricant film. In bearing operation the lubricant adheres to the moving and stationary surfaces; and by virtue of its viscosity, a positive fluid pressure develops in the film. The pressure developed sup-

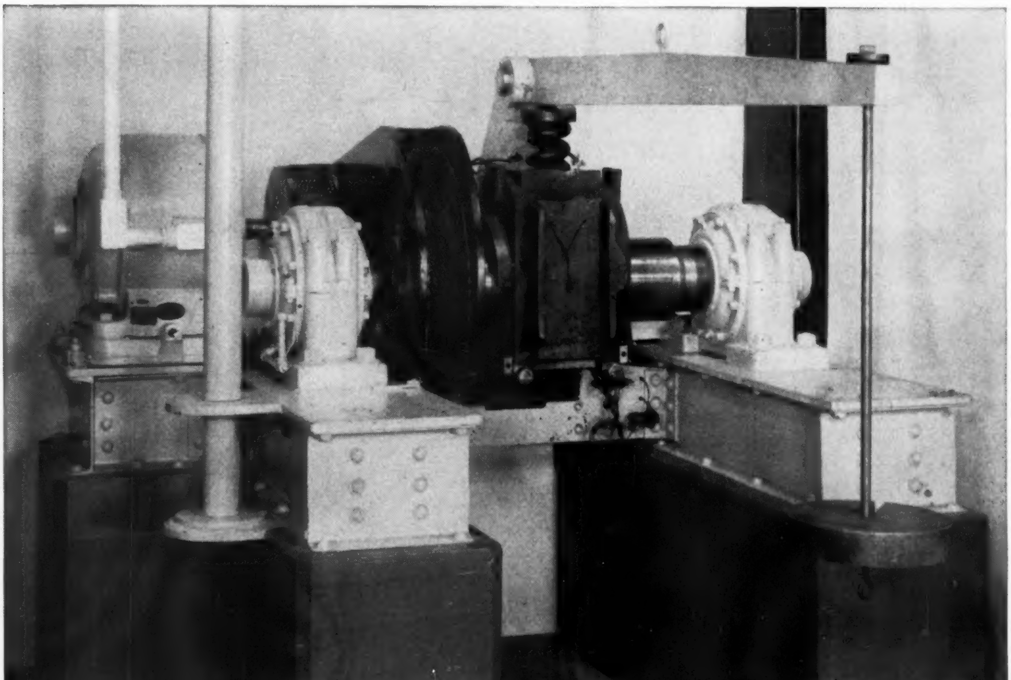


Figure 1 — Laboratory driving journal testing machine with an actual 9 x 12 inch plain bearing and box. Has figured prominently in development of the well known driving journal compounds.

ports the load and separates the metallic surfaces.

Many additional investigators, since the days of Reynolds, have made and are continuing to make substantial contributions to the theory of lubrication pioneered by the initial work with railroad lubrication.

Railroad Growth

With the improvement of the steam engine in the latter part of the eighteenth century by James Watt and its application to steam locomotion in 1814 by George Stephenson, an entirely new mode of transportation was initiated which contributed materially to a great era of expansion in the United States. In 1830 the first mechanically powered train on the American Continent was drawn by a steam locomotive built in New York. In 1869 it was possible to travel from coast to coast by rail. By 1948 the total miles of rail lines had increased from the initial 40 to 225,149 miles.

Although not the only factor contributing to the great industrial strides and the development of the United States from a few scattered settlements to a world power, the railroad played a very significant part. With scarcely more than 6 per cent of the world's population and 5 per cent of its land area, the United States has more than 29 per cent of the world's rail mileage. Agricultural and industrial prosperity, dependent upon mass movement of goods, has increased. In 1952 the United States produced 21.3 per cent of the world's wheat (exclusive of U.S.S.R. and China), owned 12 per cent of the cattle and produced 48 per cent of the steel. Industrial progress in other countries as well has accompanied the extension of this form of transportation and it is to be expected that the industrial developments in what are now more backward countries will follow this pattern. In this connection, it is interesting to note that in the past two decades world rail freight increased by 182 per cent.

Great progress in the design and construction of railway equipment accompanied the physical expansion of the railroads. Not only were advances made in comfort and safety to the traveler, but improvements were realized to increase efficiency and reliability of all rolling stock. This progress has made possible the utilization of the greater motive power as locomotive design advanced and trains became larger and faster.

Progress in railroad operation such as the replacement of the steam locomotive by the Diesel have permitted increased trip length with less frequent stops for watering and refueling. Railroad statistics show that the daily average mileage for freight cars has increased from 27 in 1920 to 46.5 in 1950, accompanied by an increased average speed

from 11.1 to 16.8 miles per hour. Also, during this same period, the average freight car capacity has increased from 42.4 to 52.6 tons. The figure which combines both the speed and load factors is the number of ton-miles per train hour. In freight service, this has increased three-fold in the years 1920 to 1952 when the ton-miles per train hour increased from 7,303 to 22,567.

Although over the last 30 years, except for the period during World War II, there has been a steady decline in passenger travel as indicated by the passenger miles, the train speeds and the trip lengths have greatly increased. For example, in 1920 the daily average passenger locomotive mileage was 158.5 miles while in 1952 it was 266.1 miles.

Progress has also been realized in the field of lubricants and lubrication. As a result of research and testing, improved petroleum products have been developed to keep pace with the demands and often-times open the way for equipment and performance advances.

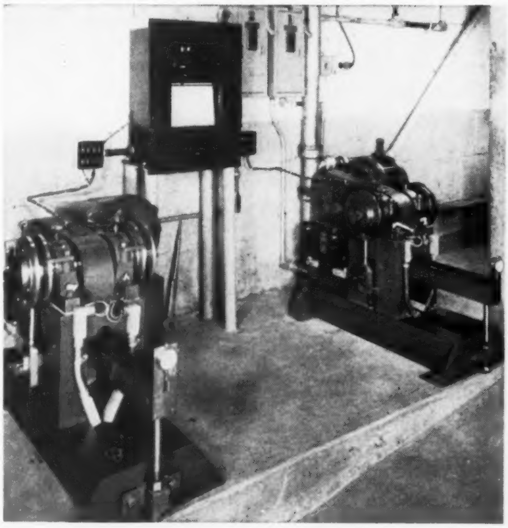


Figure 2 — These cylindrical roller bearing testers operate under heavy loads. Bearing and lubricant condition at completion of 500 hour runs used to predict performance of greases in service.

Importance of Maintenance Costs

A very important consideration in railroad operation is the cost of equipment maintenance. As shown by the following tabulations, the cost of freight and passenger car maintenance has risen rapidly from 1940 to 1952. Increased hourly labor costs have greatly affected this expense.

In addition, the number of available maintenance hours has been drastically reduced due to fewer employes and shorter working week. Car box maintenance is an appreciable part of the total mainte-

YEARLY CAR MAINTENANCE — COST OF REPAIRS

First Class Railroads

(Annual Operating Revenues above $1,000,000)

Year	*Dollars Per Car* *Freight*	*Passenger*	*Ratio of Car Repairs to Operating Revenue, Per Cent*
1940	116	1782	6.09
1942	171	2357	5.27
1944	206	3440	5.29
1946	212	3750	6.79
1948	256	4768	7.34
1950	278	4532	6.90

EMPLOYES AND PAYROLL FOR MAINTENANCE OF EQUIPMENT

First Class Railroads

Year	*No. of Employees*	*Payroll*
1940	280,719	$ 493,430,770
1942	350,347	762,740,557
1944	389,176	1,048,834,257
1946	371,150	1,104,229,042
1948	365,142	1,264,536,859
1950	348,181	1,211,043,941
1952	345,531	1,366,855,258

Statistics quoted obtained from Moody's Transportation, 1953.

nance and, hence, is subject to these same limitations.

Importance of Lubrication Research

Both the increased operating demands and the trend in maintenance economics place a premium on continued improvements in bearing design, lubricants, and lubrication practices. It is the job of research to produce these improvements. It can be seen that even small improvements will result in large over-all benefits, in the light of the more than 1,745,778 freight and 37,359 passenger cars in service.

RAILROAD JOURNAL BEARING TEST MACHINE

Over the many years of studying bearing lubrication and investigating lubrication problems in our laboratories for various applications, numerous test machines have been constructed and operated. Not a few of these have been specifically for studying the lubrication of railroad journal bearings. All of these tests have served the purpose of coming to a better understanding of the problems and have ultimately resulted in more and better lubricants.

The Railroad Journal Bearing Test Machine is one of the significant achievements in realizing the dream of the laboratory, that is, to have a bearing test machine on which full-scale journal boxes could be subjected to the load and speed conditions encountered on the actual railroad right-of-way.

Steady vertical loads which correspond to the dead weight and lading of the car can be applied to the test bearing up to a maximum of 50,000 pounds. In addition, vertical shock loads can be superimposed on the steady load to simulate the bearing loading experienced as a result of passing over rail partings, frogs, etc. Horizontal or axial loading, both steady and shock, duplicate the bearing loading resulting when cars are maneuvering on curves or passing crossovers. Maximum steady axial loads of 15,000 pounds are possible. Shock loading frequencies may be varied up to 400 cycles per minute to correspond to the simulated speed of the car. The axial loading system provides for the relative axial motion inherent in certain types and designs of boxes. Journal rotation may be varied over the range of speeds up to the equivalent of 100 miles per hour train speed.

The machine, shown in photograph in Figure 3, accommodates two full size journal boxes, one at either end of the journal. The main shaft is supported on two pedestal bearings located on either side of the vee-belt drive in the center of the ma-

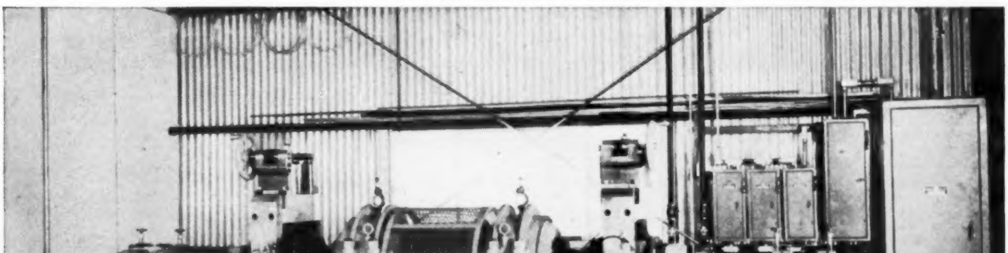


Figure 3 — Seven-ton, full-scale Railroad Journal Bearing Test Machine showing two actual 5½ x 10 inch journal boxes assembled with vertical loading yokes and axial load cylinders.

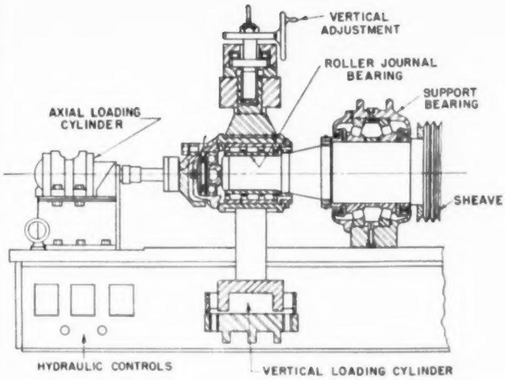


Figure 4 — Section drawing of one end of the Railroad Journal Bearing Test Machine showing details of test box, support bearing and hydraulic loading units.

chine. The vertical loading is applied through the loading yoke around each journal box which may be seen above the three pressure gages. The double acting piston-cylinder assemblies at each end supply the axial loading. Figure 4, a partial section drawing of the machine, shows some of the essential internal details such as vertical and axial loading cylinders, journal, support bearing, and sheave.

Figure 5 shows a schematic section through a roller bearing test box and loading yoke. All loading is applied by hydraulic pressure up to a maximum of 1000 p.s.i. For vertical loading, oil is supplied to the flotation load cylinder. The pressure acts against the mating loading shoe and by means of the yoke is transmitted to the top of the journal box. Vertical and horizontal adjustments permit the load to be applied exactly through the center of the bearing. By the vertical adjustment, a clearance space may be provided between the loading yoke and shoe so that the loading system floats on an oil cushion and the yoke is free to turn under bearing friction. Rotation of the system is restrained by the friction arm which is a cantilever beam with resistance strain gages mounted on it. These measure the bearing friction.

The machine is driven from the 75 horsepower motor shown in the foreground of Figure 6. The motor is coupled through a variable speed hydraulic coupling to a two-speed transmission which drives the main shaft of the machine through ten vee-belts. Emergency safety provisions include automatic shut-down for bearing overload, bearing load failure, and test or support bearing overheating.

Bearing temperatures are recorded at the control panel shown at the left of Figure 7. Bearing friction indicators, speed indicators, and electrical controls are also located on this panel. Hydraulic load system flow controls and pressure gages, indicating the bearing loads, are located on the front of the machine just below the main base plate.

The hand crank shown on the photograph is used in conjunction with the strain gages to locate the load accurately over the journal center before the start of a run.

LUBRICATION OF ROLLER BEARING JOURNAL BOXES

The application of roller bearings on railway rolling stock is not new; the first installations were made in the early nineteen hundreds. Although some of these early installations experienced problems, the performance of many was quite satisfactory and served to establish roller bearings as an important part of railroad operating equipment. With the increased speeds of operation and the concern for passenger comfort, it was quite natural that the roller bearing should be first applied in that type of service. At about the same time, the application of roller bearings was made to the axles of steam locomotives, first to the trucks and later to the driving wheels. With the Diesel-electric locomotive, roller bearings were used almost exclusively from the beginning. Although the application to freight rolling stock has not been very general, some cars are being equipped with roller bearings. A great deal of experimental work has been conducted by bearing manufacturers, railroads, and lubricant suppliers to explore the use of roller bearings for this service.

Roller bearings usually consist of two races, a cage, and rollers. The elements of all rolling contact bearings require careful design and accurate construction. From a first consideration it might be expected that friction losses could be almost com-

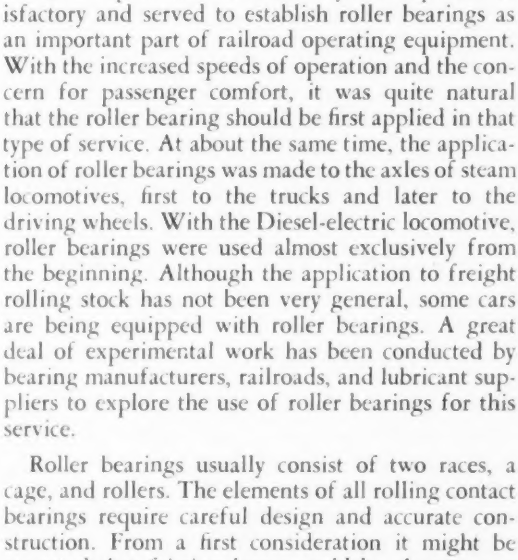


Figure 5 — Schematic section through a roller bearing journal box of Railroad Journal Bearing Test Machine showing vertical loading yoke and flotation to permit bearing friction measurement.

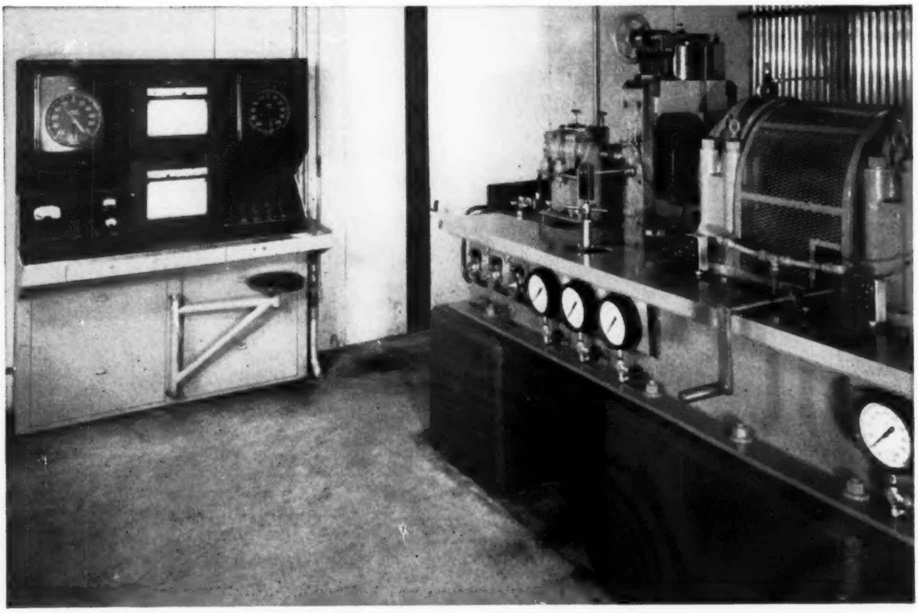


Figure 7 — Railroad Journal Bearing Test Machine with control and instrument panel. Hydraulic controls and load pressure gauges visible in channel section above mounting pedestals.

pletely eliminated in this type of bearing which essentially places rollers between two plane surfaces. However, the action is not nearly so simple and friction losses do occur. Geometrical inaccuracies and configurations of the bearing surfaces cause some resistance to motion. Also, since no materials are perfectly rigid, deformations of the rolling members cause slipping to occur and, in turn, resistance to rolling.

The fact that roller bearings often operate for long periods of time without attention, and even with very thin coatings of lubricants on the parts, frequently leads to the erroneous conception that

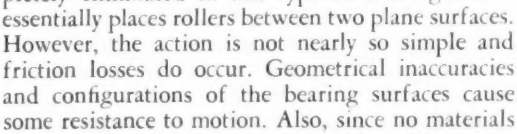


Figure 6 — Rear view of Railroad Journal Bearing Test Machine showing drive motor. Screen guard covers ten Vee-belts connecting transmission output shaft to sheave on test journal.

the roller bearing needs no lubrication or its lubrication is relatively unimportant. Also, some confusion is added to the overall picture because these bearings may operate at a higher temperature and have somewhat higher friction when lubricated.

Lubrication of a roller bearing serves the following functions:

1. Providing a film to lubricate the sliding contact areas between the rolling elements and their retainers.

2. Providing protection for the highly finished accurately ground surfaces against rust and corrosion.

3. Assisting in the formation of a seal against the entrance of dirt and other foreign matter.

4. Cushioning the shock and distributing the load as the rolling elements enter the loaded zone.

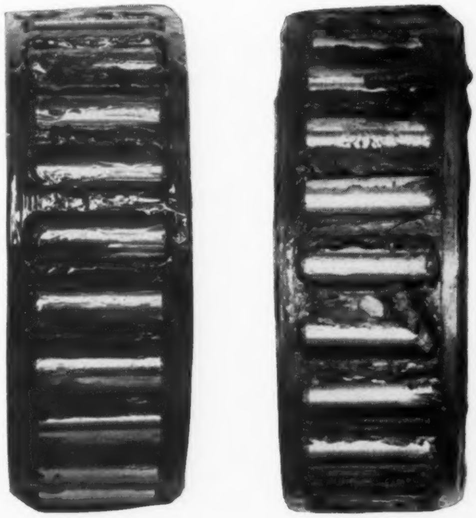
5. Aiding the dissipation of heat.

The very accurate dimensions and fine surface finishes required for the satisfactory operation of roller bearings can easily be destroyed if the proper lubricant is not used. Lubricant selection should be based upon the bearing operating conditions, i.e., speed, load and temperature. However, such factors as bearing housing design, accessibility for relubrication, and possibilities for contamination by moisture and foreign matter have an important in-

fluence on the lubricant choice. In general, it has been the practice to use as light a lubricant as can be successfully retained in the bearing. Both car oils and greases are being used to lubricate roller bearing car boxes; however, the present tendency is toward more wide-spread use of grease. In spite of the higher cost of grease over car oil, the longer service life and less required makeup give an overall economy with the grease. Grease has the advantage over oil in serving as a better seal to prevent the entrance of foreign matter. It is also more easily retained in the journal box. In railway service, the desirable goal is to renew the lubricant only at wheel turnings and at wheel renewals.

Roller Bearing Lubrication Research

Roller bearing lubrication has been the subject of considerable research and a wealth of data has been developed to show the performance of lubricants over a wide variety of operating conditions. The Railroad Journal Bearing Test Machine provides another tool which extends the scope of the laboratory testing to full-scale car bearings under the conditions of dynamic loading and speed encountered in service. Test methods developed in the laboratory for the roller bearing journal boxes make possible the evaluation of oils and greases for this service under controlled and repeatable conditions. The extensive tests which have been conducted



Grease A Grease B

Figure 8 – Two roller and cage assemblies at completion of simulated service run on Railroad Journal Bearing Test Machine. Differences shown in performance of Grease A and Grease B by amount and condition of the grease on these bearing elements.

have shown excellent correlation with actual service.

By systematic variation of the grease components and evaluations in the full-scale test bearings, essen-

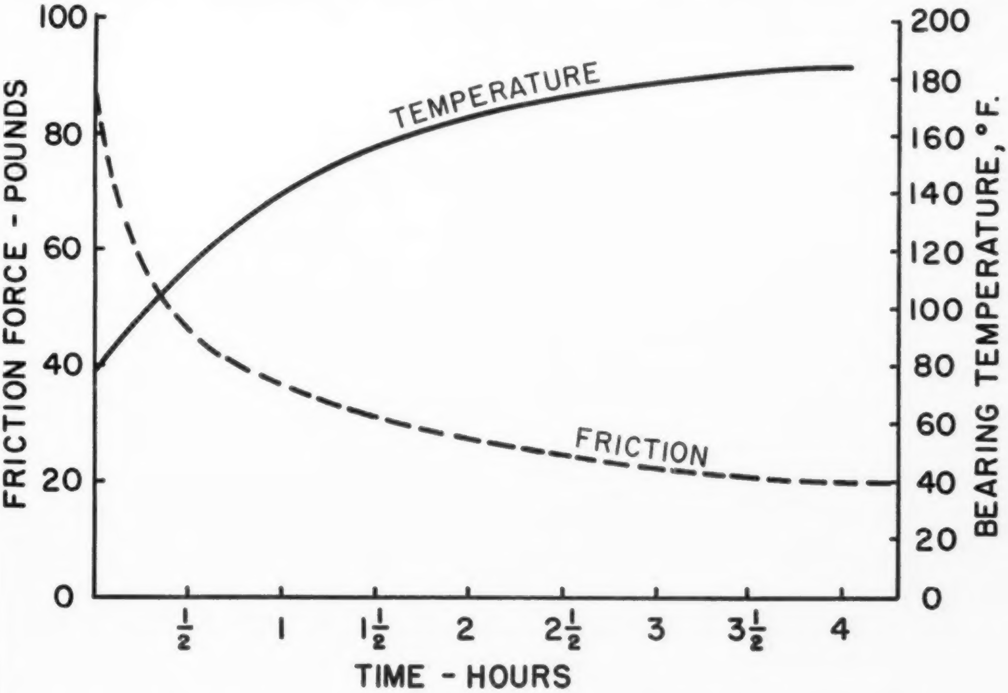


Figure 9 – Equilibrium bearing temperature friction curves for a grease lubricated roller bearing from results on Railroad Journal Bearing Test Machine.

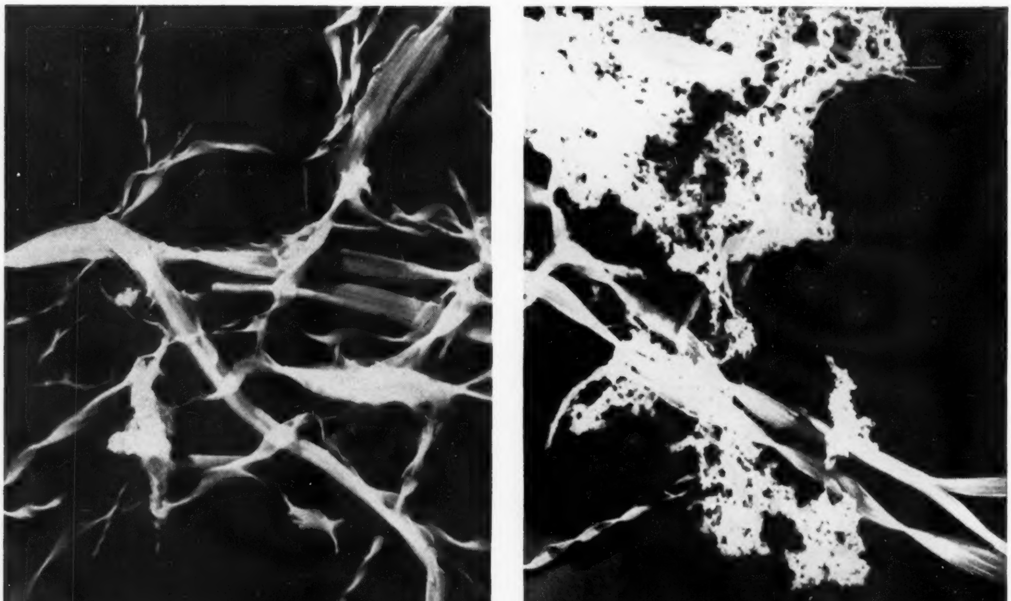


Figure 10 — Electron micrographs of samples of railroad roller bearing grease. At the left the new grease. At the right the same grease after having completed satisfactory operation in a roller bearing journal box.

tial information has been developed which leads to a better understanding of the reasons why certain lubricants are more effective than others. Results have also shown the factors which influence grease performance and have given information aiding in the selection of the material to be used in grease formulations.

The laboratory tests have made possible the obtaining of bearing friction and temperatures in roller bearings of different manufacture and design under varying test conditions. Lubricant leakage, condition of the various bearing elements, bearing deposits, and grease changes can be evaluated. The latter can be accomplished by examining the chemical and physical condition of the grease after it has been subjected to the service-type operating conditions. The electron microscope has proven to be an invaluable tool in coming to a better understanding of the performance of greases. Information has been obtained on the influence of bearing operating variables on changes in grease structures. Also, the effects of composition and manufacturing processes on grease structure have been studied so that greases can be better designed to have specific characteristics.

Bearing frictions and equilibrium temperatures afford one means of studying the effect of oil viscosity, lubricant quantity, and rotational speed in the bearing operation. These same criteria may be used to determine optimum grease charge for the bearing and the resistance to channeling and working.

LUBRICATION OF PLAIN JOURNAL BOXES

In spite of the replacement of plain bearings on passenger, locomotive, and some freight service, it is estimated that there are more than 14,000,000 solid type journal boxes on freight cars alone on the American railroads. The plain bearing assembly, as generally employed, is of relatively simple construction as shown in Figure 11. The internal parts are the bearing, journal, and wedge. The box provides the housing, closed at one end with a lid and at the other end with a dust guard.

The bearings, in general, are fabricated as cylindrical segments of different material than the axle or journal with which it is to operate. A common bearing material is brass with a babbitt lining which provides conformability with the journal. The wedge serves to distribute the load and to seat the bearing properly.

In most installations, oil is fed to the journal from the oil reservoir in the bottom of the journal box by capillary action of a packing which most commonly is cotton waste. In some cases, packing retainers are used to help maintain the waste in position during switching and "humping" operations. "Humping" is the procedure used in the classification yards to assemble cars into a train. In the operation, the cars are pushed by a locomotive to a raised section of track called a "hump" from which the car then coasts by gravity through a switch to the particular

track on which the train is being made up. The impact upon contact with the other cars on the train causes relative motion between journal and bearing and waste dislodgement.

When operating with a sufficient supply of lubricant, the bearing will be completely separated from the journal by a wedge-shaped, load-supporting oil film. Under such conditions, the bearing friction is due mainly to the fluid friction resulting from the viscosity of the oil in the clearance space. Due to the frictional heat developed, bearings operate at temperatures higher than the ambient. This frictional heat dissipates into the journal and bearing, and the greater the friction, the greater the differential between the bearing and the ambient temperature. To a considerable degree, this temperature rise is indicative of the efficiency of the lubrication.

When more heat is generated in a journal box than can be dissipated, a bearing failure ultimately results. In the waste packed bearing, the friction of the packing against the journal as well as the oil film friction is a source of heat. The packing friction and also the feeding or wicking of the oil are functions of the type and size of the threads in the packing and the oil viscosity. By varying these, it is possible to exert some control over the packing friction. Low viscosity oils are reported to produce less packing friction, carry less lint and foreign matter to the bearing, and feed more oil to the journal.

Hot Boxes

The failure of the bearing to function properly results in overheating which in railroad circles has become known as a "hot box". The occurrence of a "hot box" is serious because it requires setting out the car from the train for bearing repair or replacement. Since this causes delays in schedules, it can be costly. Car miles per "hot-box" set-off vary considerably depending on the season and the particular railroad involved. Some roads have a disproportionate number of "hot boxes" because of contaminating materials being handled, short haul traffic, or some other peculiar condition. If "hot boxes" are not detected sufficiently early they can lead to more

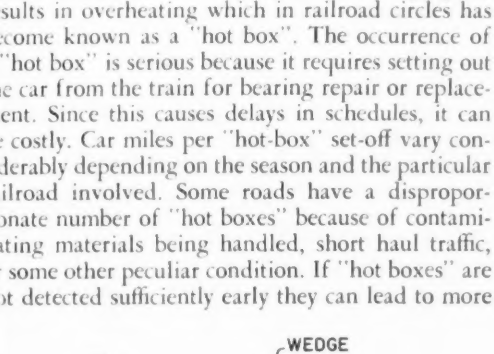


Figure 11 — A section drawing showing the main parts of a plain bearing railroad journal box.

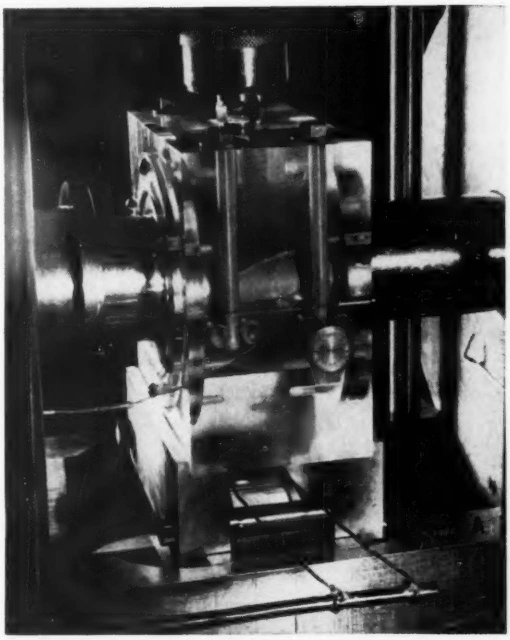


Figure 12 — Transparent bearing as used to visually study the formation of fluid films in plain bearings.

serious damage to the bearing and axle and even result in train accidents.

The incidence of "hot boxes" is very closely related to seasonal variations in temperature particularly during extreme temperature conditions. The lower viscosities resulting from the hot weather probably affect the bearing to reduce the minimum film thicknesses. In low temperatures the tendency for waste roll and grab is much greater because of the increased viscosity of the oil. Also, with increased oil viscosity the feeding or wicking of the oil is much reduced.

The occurrence of "hot boxes" following closely after the repacking of journal boxes and the installation of new brasses has been observed. If distress is going to occur from this source, experience has shown that it most often happens within a few miles or a short time after leaving the terminal.

Some shifting of waste usually will occur during "humping" as well as during normal operation of a car. This may cause the journal to pick up waste threads and carry them into the clearance space where they cause localized high friction and hot spots which further develop into general bearing overheating. In more severe cases a very substantial portion of the dislodged waste may be caught between the journal and the brass. Under some conditions, waste settling occurs to the extent that the packing loses contact with the journal and no feeding of oil to the bearing is possible.

Because of poor or improperly seated seals, for-

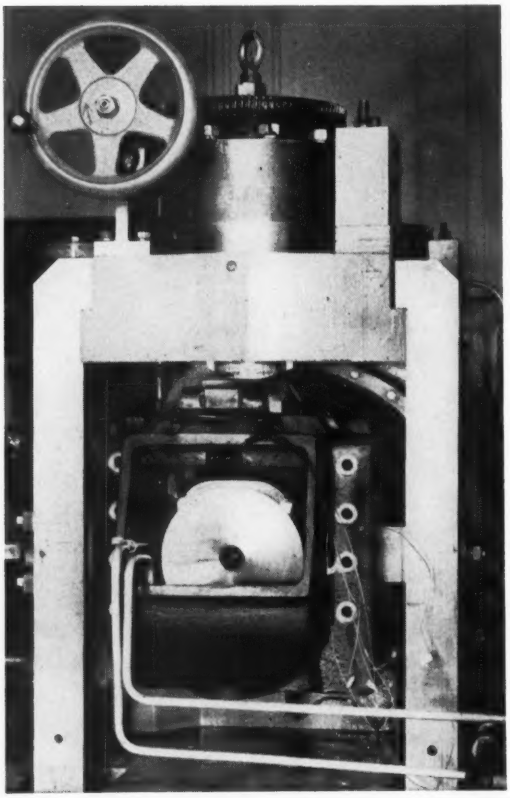


Figure 13 — This 5½ x 10 inch plain journal box is equipped with spray lubrication for car oil studies on the Railroad Journal Bearing Test Machine.

eign matter such as dirt, snow, rain and other undesirable materials find their way into the journal boxes where they contaminate the lubricant and may cause changes in its properties.

Inspection and preventive maintenance have become more difficult since present day trains are assembled and depart much more rapidly. The less frequent and shorter stops of the modern train do not provide sufficient time or occasion for as thorough inspections and servicing as had been customary in the past. Much more rapid interchanging of cars and shorter periods of time in which the cars are on the same road are also making maintenance programs difficult to schedule. As previously mentioned, the cost of maintenance has increased primarily because of higher labor costs. Also, the personnel available for inspection and servicing has decreased.

With the rapid accelerations now possible with the high powered Diesel-electric, bearing wear-in periods are not as gradual and there is less time for the bearing to make adjustments for abnormal conditions. Also with rapid acceleration there may be insufficient time for the establishment of an adequate lubricant film. Consequently, under these conditions high friction will occur and high temperatures will develop.

Because of the constantly increasing maintenance costs and the continued interest in improving railroad service and effecting economies in operation, a much greater emphasis is being given to the subject of "hot boxes". Bearing manufacturers, railroads and lubricant suppliers are studying the problem and making concerted efforts to achieve a satisfac-

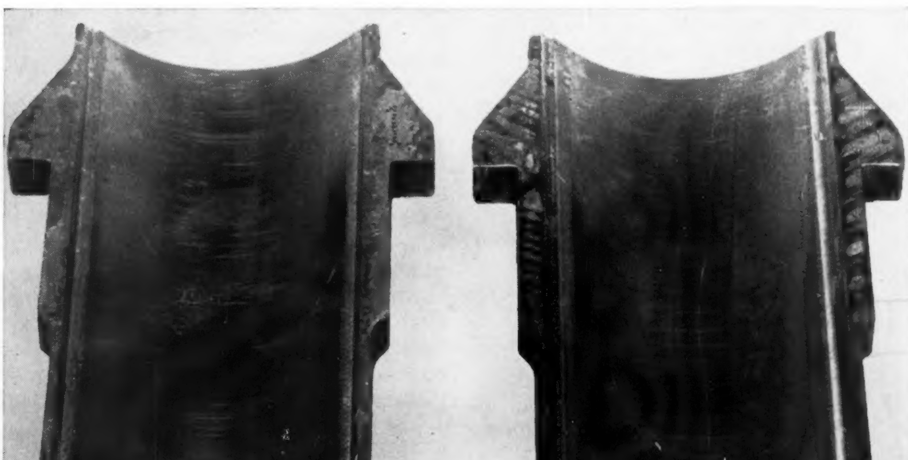


Figure 14 — These plain bearing brasses have been subjected to typical railroad service conditions on the laboratory test machine. Wiped surface results from mild flow of babbitt to conform to journal.

Figure 15 — This plain car box is being run in the laboratory under load with grease lubrication. Considerable circulation of the grease to the bearing can be seen as a result of axle rotation.

tory solution. Progress has been realized in all fields of endeavor. Improvements have been made in bearing materials, in bearing design, and in the finishing and dimensioning of the various elements. Concern for the type of packing has led to better selection of the material used in the waste as well as improved methods for handling and reclaiming it. Designs have been suggested which substitute other types of oilers for that commonly used. Various mechanical devices such as waste retainers have been devised to overcome the shortcomings of waste packings. Several rather radically new bearing designs, at least for railway service, which provide much more accurate fitting of journal and bearing with more positive lubricant supply mechanisms are being suggested. A number of these are under test either in laboratories or on the roads. It is inevitable that some of these will result in improvements in the reliability of this already tried and proven mechanism.

Plain Bearing Lubrication Research

Research work at our laboratories has been continued to further extend and apply the fundamentals of hydrodynamic lubrication to plain bearing studies in general. Special emphasis has been directed toward the study of the lubrication of the solid-type railroad journal box and its specific problems. Basic studies have been conducted to determine the effects of oil viscosity, journal speed and load, bearing dimensions (such as clearance and length to diameter ratio), and oil flow on the performance of bearings as measured by bearing friction, bearing and journal temperatures, lubricant film thickness, journal eccentricity, bearing arc, and film pressure distribution. Complete bearing performance data, including the film thickness measurements, have been obtained over a wide range of operating conditions with numerous types of lubricants.

To further enhance the understanding of these very complex lubrication phenomena, transparent bearings have been specially constructed so that under actual bearing operation the formation of the fluid films could be observed visually. By means of high speed photographic techniques the phenomena were recorded for detailed analysis and study. By the introduction of colored dyes into the lubricant films and then observing the distribution of the dye throughout the film, a much clearer understanding of the circulation of lubricants within the film was developed. Differences between the behavior of various types of lubricants in this respect were marked.

Plain bearing studies on the full-scale railroad journal test machine are also possible since this tester had been designed to accommodate all types and makes of railroad bearings in the sizes from $5\frac{1}{2}$ by 10 inches through $6\frac{1}{2}$ by 12 inches. The shaft for the plain bearing studies had been designed so that the test journal sections were identical to the car axle ends as specified by AAR. To eliminate any possible influence from variations in the waste packing and the packing procedures on the oil performance studies, some testing was conducted in which a special oil spray and circulation was provided. Figure 13 shows a photograph of a close up of one of the test boxes on which the circulation system has been installed. Oil picked up by a pump from the journal box reservoir was sprayed against the journal through a series of orifices located axially along the journal below the brass. Heat ex-

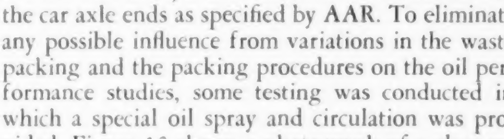


Figure 16 — Typical curves plotted from plain bearing data obtained with the Railroad Journal Bearing Test Machine.

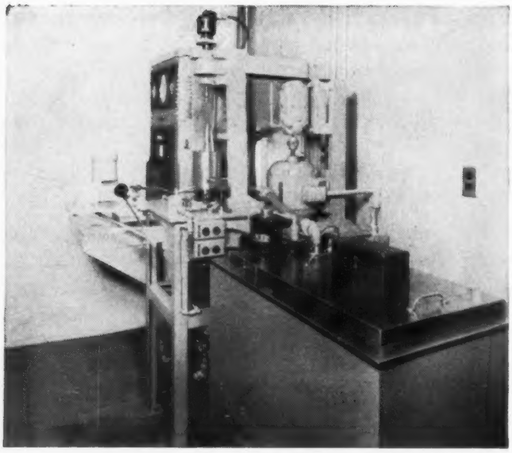


Figure 17 — This high rate of shear rotational viscometer is used to study the flow behavior of greases under controlled speed and temperature conditions corresponding to actual bearing service.

changers in the system provided a means for control of oil temperature by either cooling or heating.

The effects of oil viscosity on bearing temperature and friction have been determined and studies conducted to show the influence of speed, load, and viscosity on the bearing performance, particularly in the operating zone where full hydrodynamic conditions might be giving way to boundary lubrication conditions. This operation is not unlike the starting, stopping, or low speed service on the railroads. By examination of the wear pattern on the bearing surface which has been run under such conditions, particularly when some wiping occurs, it is possible to deduce the causes and effects. Influences of various bearing materials and oils and EP additives in the oils on the performance under such conditions are studied. The effect of break-in or run-in procedure on a new bearing has been found to be quite important relative to the load carrying ability without overheating.

Evaluations have also been made using waste packing in the journal box to determine the effects of oil viscosity on the friction and running temperature of the bearing. Under operating conditions with flooded lubrication as furnished by the spray system, bearing frictions and operating temperatures were lower than when the lubrication was supplied from the waste packing. This was due not only to more satisfactory lubrication of the bearing but also to elimination of the friction which results from the waste contacting the journal.

Studies have also been made by means of special bench tests to determine the effect of lubricant viscosity, thread quality, and type on the wicking or capillarity of the waste packing. The tests designed to evaluate this property, independently of the bearing, show that there are marked differences in oils and wastes in this respect. String grabbing tendencies of car oils have been evaluated both at high and low ambient temperature conditions in full-scale bearing test stands.

Grease Lubrication of Plain Bearings

Many investigators concerned with the "hot box" problem consider that the elimination of the waste packing is essential to a completely satisfactory and reliable plain bearing for railroad service. In the past several years this approach has been evidenced by numerous papers published in technical journals and presented to technical societies. The rather fundamental studies which were conducted on the previously mentioned bearing test machines with grease as a lubricant, suggested the feasibility of grease for the lubrication of plain car boxes. In particular, these studies showed that a hydrodynamic load supporting film was developed with grease in much the same way as for a fluid type lubricant and the coefficients of friction were of the same order of magnitude. Observations of the flow of grease in a plain bearing indicated that grease exhibits somewhat directional flow properties. This was indicated in the bearing by the relatively low resistance to flow in the direction of journal rotation while in the axial direction there was resistance to flow in that end leakage was low.

The principles observed in the experimental bearing have been applied to the full size car journal box on the railroad journal bearing tester. Grease was charged in the box to a level sufficient for the journal to dip into and pick up grease and carry it into the clearance space. The investigations which are continuing, show the influence of grease fluidity on the circulation of the grease in the box. Experimental work shows some of the factors, both in the bearing and the grease properties, which can be varied to influence the bearing performance. Figure 15 shows a photograph taken through the open end of the journal box during the operation with grease lubrication. The circulation of the grease is quite readily visible.

Through continued research and development in this field of bearing lubrication, it is certain even greater progress and achievements will be realized.

CONCLUSION

During the history of railroading, even from the early days of the wood-burning steam locomotive, the operating requirements of railroad journal bearings have become increasingly severe. The challenge in this field has been continually met and the railroads, their associated organizations, bearing manufacturers, and lubricant suppliers, through research and development, have made many advances in the field of bearing lubrication. It is certain that their continued efforts will result in even greater achievements.

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UNRETOUCHED PHOTO showing bearing after approximately 750,000 miles of service. Note that grease has retained its consistency. This is typical of the long-lasting protection afforded by *Texaco 979 Roller Bearing Grease.*